Deepwater Horizon / Mississippi Canyon 252 Oil Spill Natural Resource Damage Assessment

TECHNICAL REPORT: QUANTIFICATION OF FLEDGLINGS LOST IN 2011

Prepared by the U.S. Department of the Interior, Fish and Wildlife Service

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1 INTRODUCTION

The *Deepwater Horizon* / Mississippi Canyon (MC 252) Oil Spill ("spill") began in late April 2010 in the northern Gulf of Mexico. The Department of the Interior ("Department") bureaus responsible for the management and protection of avian resources (i.e., the U.S. Fish and Wildlife Service and the National Park Service), together with the states of Florida, Alabama, Mississippi, Louisiana, and Texas (collectively referred to as the "Natural Resource Trustees") evaluated oil spill-related injuries to birds.

One type of natural resource injury pertaining to birds was mortality due to the spill. The Department estimated avian mortality that occurred from the time the spill began to September 30, 2010 (the date by which searches for dead birds and birds needing rehabilitation had largely ended) in nearshore areas of the northern Gulf of Mexico using the Shoreline Deposition Model and Lost at Sea Factor (herein referred to as simply the "Shoreline Deposition Model"; IEc 2015a), the "Excluded Regions" methodology (USFWS 2015b), and information on "colony sweep" birds (USFWS 2015a). The Department estimated separately the number of fledglings lost in 2010 (USFWS 2015c). The Department estimated the additional, delayed bird mortality that likely occurred after September 30, 2010 using the Live Oiled Bird Model (LOBM), which considers data on bird abundance, oiling rates of live birds that were not incapacitated enough to allow capture and rehabilitation, and anticipated fates of birds oiled at various degrees (USFWS 2015d). Breeding-aged birds that died after the 2010 breeding season ended would not have existed to reproduce in 2011. This document presents the methodology and results for estimating the number of fledglings that would have been produced by those birds that died *after* the end of the 2010 breeding season-- more specifically, the number of 2011 fledglings not produced due to the deaths of breeding-aged birds occurring between August 7, 2010 and August 7, 2011. The report also discusses the uncertainties and limitations involved with the methodology.

2 BACKGROUND

Effects of the oil persisted well after the capping of the Macondo well in July 2010. Oil persisted in the environment (OSAT-2 2011; OSAT-3 2013, 2014), presenting exposure risks to birds. The productivity of breeding birds in 2011 and the healthy survival of their fledglings could have been adversely impacted in the following ways:

1. Birds of breeding age could have been exposed to oil in 2010 and/or 2011 at levels which could have sickened them enough so that gametes were nonviable in 2011, producing an abnormally high number of nonviable eggs laid or smaller than normal clutch sizes in 2011. The resulting natural resource injury metric would be chicks not produced.

2. Oiled breeding adults could have transferred oil to viable eggs in the nest while incubating them in 2011, causing the eggs to smother in oil or become nonviable due to oil toxicity. The resulting natural resource injury metric would be egg mortality.

3. Oiled breeding adults could have transferred oil to chicks hatched in 2011 through physical contact, exposing chicks to oil toxicity. The resulting natural resource injury metric would be chick mortality or reduced fitness.

4. Breeding adults could have fed chicks hatched in 2011 contaminated prey that could have caused toxic effects in the chicks. The resulting natural resource injury metric would be chick mortality or reduced fitness.

5. Birds of breeding age could have died from spill-related causes at any time before or during the 2011 breeding season. If these birds had already laid eggs in 2011, the eggs or chicks would likely not survive. The resulting natural resource injury metric would be chick/egg mortality.

6. Pre-fledging chicks, hatched in 2011, could have been exposed to oil in their environment while loafing outside their nests, causing toxicity. The resulting natural resource injury metric would be chick mortality or reduced fitness.

7. Oil spill cleanup efforts conducted near breeding birds in 2011 could have kept birds from properly incubating eggs or tending to chicks. The resulting natural resource injury metric would be chick/egg mortality.

Direct quantification of the loss of 2011 fledglings due to the oil spill was complicated by the following factors.

1. The Trustees did not systematically search for bird carcasses during the 2011 breeding season. Most carcass searches ended after September 30, 2010.

2. The Trustees did not directly measure the effect of the oil spill on the productivity of colony and non-colony breeding birds in 2011 (i.e., no direct measure of the number of fledglings produced per nest). The Trustees did collect data on the numbers of birds and nests in colonies in 2010-2013 through aerial photography (Colibri Ecological Consulting and R. G. Ford Consulting Company 2014); however, the photographs cannot be used to count chicks (which would be shielded from photographic view by attendant parental birds) or fledglings (which could move away from colonies). In addition, the lack of detailed colony information from before the spill complicates the translation of the photographic information into the number of nests that may have been missing due to the oil spill.

Given the lack of direct information regarding lost 2011 fledglings, the Department used an alternative method for estimating the number of lost 2011 fledglings, described below.

3 FEASIBILITY OF ASSESSING NATURAL RESOURCE INJURY REALIZED THROUGH DIFFERENT EXPOSURE PATHWAYS

As summarized in Section 2 (Background), there were several pathways through which exposure to oil could lead to adverse effects to adult productivity and survival of young during the 2011 breeding season. The types of adverse effects themselves, however, can be categorized as chick/egg mortality, chick reduced fitness, and chicks/eggs not produced. For pre-fledgling chicks, surviving to successfully fledge is dependent on adequate fitness of the chick, barring external factors such as predation and extreme weather. Thus, for purposes of this assessment, reduced chick fitness was treated as functionally equivalent to chick mortality. That resulted in two endpoints upon which to focus the quantification of natural resource injury in 2011 fledglings: chick/egg mortality and chicks/eggs not produced.

There were insufficient data available to assess injuries caused through each of the exposure pathways described in Section 2 with enough specificity to eliminate double-counting of injuries. A chick could suffer adverse effects from being exposed to oil through more than one pathway. For example, an oiled parent may transfer oil to its chick by body contact, as well as through feeding its chick contaminated prey, and a precocial chick leaving its nest soon after hatching may contact oil in its environment. If the chick died due to oil exposure, it would not be possible to determine to what degree each pathway contributed to the death. In this example, quantifying the injury through each of those pathways and then parsing out the potential double-counting would be treacherously tedious, if not impossible. Additionally, much of the supporting information that would be required to calculate injuries by most of the specific pathways was not available.

The only pathway for which sufficient data existed relevant to lost 2011 fledglings was the fifth pathway listed in Section 2: birds of breeding age could have died from spill-related causes at any time before or during the 2011 breeding season. If these birds died after beginning the nesting process in 2011, their eggs/chicks would likely not survive. If these birds died before the 2011 breeding season, they represent eggs/chicks not produced in 2011.

Data were available to estimate the number of breeding-aged birds that died due to the spill, from the time the spill began through 2011. Depending on when these birds died, the first breeding season for which they would not have been present was either 2010 or 2011. The loss of 2010 fledglings was quantified in the technical report Quantification of Lost 2010 Fledglings (USFWS 2015c). This report evaluates that loss of 2011 fledglings due to the mortality of breeding-aged birds that died after the end of the 2010 breeding season based upon the mortality estimates for breeding adults in the nearshore area.

4 METHOD FOR QUANTIFICATION OF LOST 2011 FLEDGLINGS

The Department's preferred method for estimating the lost 2011 fledglings, given the available data, was to estimate the number of fledglings that would have been produced in 2011 had certain breeding-aged adults not died due to the spill prior to the 2011 breeding season. Similar to the method used to calculate lost 2010 fledglings (USFWS 2015c), the general conceptual method involves multiplying a number of dead breeding adults by the average annual productivity as described in published, scientific literature (Figure 1). The major assumption in this approach is that, but for the spill, the dead breeding adults would have produced fledglings consistent with species-specific, published, average productivity rates. The application of the methodology is more complex than this conceptual model. The specific data inputs and assumptions necessary to implement the methodology are described below.

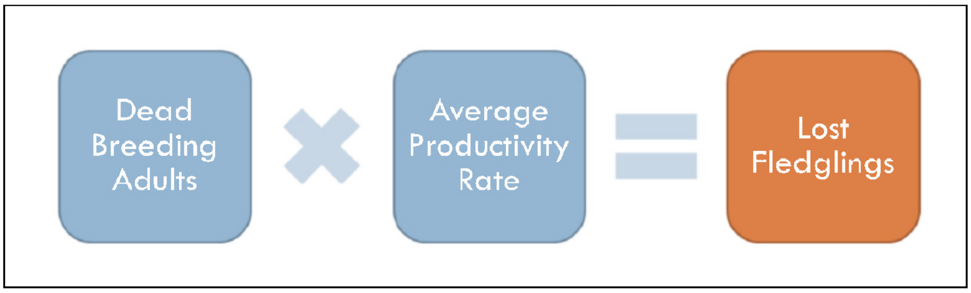

Figure 1: Conceptual approach to calculating the lost 2011 fledglings using the average annual productivity.

4.1 ASSUMPTIONS

The following assumptions simplified the calculation of lost 2011 fledglings.

4.1.1 But for the spill, the dead breeding adults would have produced fledglings consistent with species-specific, published, average productivity rates.

Productivity information specific to the northern Gulf of Mexico is not available for all avian species impacted by the spill. Gulf-specific information was used whenever available, but in some situations, it was assumed that data from other geographic areas were sufficient for use in this calculation of lost fledglings. Many published studies did not describe the environmental conditions that may have influenced productivity during the study. Therefore, it was necessary to assume that the environmental conditions that influence avian productivity were sufficiently comparable between the northern Gulf of Mexico and the locations from which the productivity information were obtained. But for the spill, productivity would have been consistent with published, average productivity rates.

4.1.2 Breeding birds killed by the spill would have attempted to rear only one clutch of eggs or brood of chicks in 2011

The avian breeding season in the warm northern Gulf of Mexico area is relatively long. Some species of birds could have enough time to successfully rear two broods of chicks if optimal conditions existed. For purposes of simplifying the estimation of lost 2011 fledglings, the Department assumed that breeding birds only attempted to rear one clutch or brood in 2011.

4.2 CALCULATION INPUTS

For the sake of simplifying the lost 2011 fledgling calculation, only the species with the highest mortality estimates in the Shoreline Deposition Model and the LOBM were considered. These consisted of the top 14 species in the Shoreline Deposition Model, which cumulatively comprised up to 91% of the Model's output, and the top 18 species in the LOBM, which cumulatively comprised up to 99% of the LOBM mortality. Several species were common to both of these groups. Thus, a total of 24 species were used in the lost 2011 fledgling calculations, out of the over 100 species that were documented to be impacted in any way by the DWH spill.

4.2.1 Number of dead breeding-aged birds not available to reproduce in 2011

The calculation begins with identifying the number of dead breeding birds relevant to the 2011 breeding season (DBB_{2011}). The relevant number of breeding-aged birds was derived from two sources:

1) the avian mortality that occurred between August 7, 2010[1] and October 1, 2010, as estimated through the Shoreline Deposition Model and Excluded Region estimation, along with information on "colony sweep" birds; and
2) the avian mortality that occurred on October 1, 2010 or later, as estimated by the Live Oiled Bird Model.

The first component of DBB_{2011} was derived from mortality estimates for the time period between August 7, 2010 and October 1, 2010. The mortality estimates from the Shoreline Deposition Model, Excluded

[1] For purposes of the lost fledgling calculations, the Department considered August 7, 2010 to be the end of the 2010 breeding season, by which time most young should have fledged (USFWS 2015c).

Regions estimation, and "colony sweep" birds were used. The Shoreline Deposition Model estimated the total bird mortality during the time period from the start of the spill to September 30, 2010 for nearshore areas within the northern Gulf of Mexico. However, these mortality results covering the period August 8, 2010 to September 30, 2010 ($SDM_{afterAug7}$) contained some breeding-aged birds that would not be able to reproduce in 2011. Thus, the Model was also run for the truncated time period of the beginning of the spill to August 7, 2010, specifically for the lost fledgling calculations. The difference in outputs between the full model and the truncated model represented birds (regardless of age) that died after the end of the 2010 breeding season but before October 1, 2010, as estimated by the Shoreline Deposition Model.

Secondly, there was a certain subset of bird records in the DWH Collected Birds Dataset[2] that did not have associated search data sufficient to allow their incorporation into the Shoreline Deposition Model; these "colony sweep" birds[3] were therefore not part of the Model output, but they represent additional birds that likely died between August 7, 2010 and October 1, 2010.

Thirdly, there were regions of the northern Gulf of Mexico that could not be addressed by the Shoreline Deposition Model, so bird mortality in these areas was estimated using an Excluded Region methodology (USFWS 2015b). The portion of this estimate that occurred between August 7, 2010 and October 1, 2010 ($ER_{afterAug7}$) is relevant to the lost 2011 fledgling calculation.

Combining the subset of Shoreline Deposition Model output for after August 7, 2010, the subset of the Excluded Regions output for after August 7, 2010, and the "colony sweep" birds yielded the total mortality estimate for birds (regardless of age) occurring after the fledging season of 2010 ($M_{AFS2010}$), i.e., between August 7, 2010 and October 1, 2010, that is relevant to the 2011 lost fledglings calculation.

$$SDM_{afterAug7} + \text{"colony sweep"} + ER_{afterAug7} = M_{AFS2010}$$

The proportion of $M_{AFS2010}$ that consisted of breeding-aged birds was isolated using data from the DWH Collected Birds Dataset, considering only those records included in the Shoreline Deposition Model and dated August 8, 2010 through September 30, 2010, as well as the records identified as "colony sweep" birds. These proportions ($PB_{MBS,AFS2010}$) were applied to $M_{AFS2010}$ to yield the total number of breeding-aged birds that died between August 7, 2010 and October 1, 2010.

The second component of DBB_{2011} was derived from the output of the LOBM ($LOBM_{output}$), and specifically the subset of breeding-aged birds. Age class data collected during the oiling rate observations on colonial waterbirds (Evers et al. 2010) and wintering open-water waterbirds (Evers et al. 2011) were used to identify the proportion of breeding adults (PB_{LOBM}) in the LOBM output.

$$(M_{AFS2010} * PB_{MBS,AFS2010}) + (LOBM_{output} * PB_{LOBM}) = DBB_{2011}$$

Further detail on identifying the proportions of breeding-aged birds are provided below.

[2] DWHBirdsCollected_DraftValidated_8.28.15.xlsx

[3] After the 2010 breeding season ended, access was regained to several breeding bird colonies that had been off limits in order to protect breeding birds from the additional stress from human activity. From August 28, 2010 through September 13, 2010, special searches of breeding bird colonies were conducted to collect carcasses; these searches were termed "colony sweeps." Although these birds were collected in late August and September, it is possible that some of these birds actually died before August 7, 2010 and should be included in the lost 2010 fledgling calculation. However, data is not currently available to allow identifying this subset of birds. Thus, all "colony sweep" birds were treated as if they had died after August 7, 2010.

4.2.1.1 Proportion of breeding-aged birds to be applied to $M_{AFS2010}$

The inputs to the Shoreline Deposition Model included bird records from the DWH Collected Birds Dataset regardless of age class. In other words, some dead 2010 fledglings (and other birds younger than breeding age) were collected and were listed in the DWH Collected Birds Dataset. The Shoreline Deposition Model used all of these birds to calculate avian mortality, because the Model considers each bird collected as representing some number of other birds not collected, applying a multiplier to collected birds to estimate total mortality. Each chick or fledgling in the DWH Collected Birds Dataset potentially represents other similarly sized birds (regardless of age class) that were not collected. The output of the Shoreline Deposition Model is in terms of generic "birds," without reference to age. Similarly, the output of the Excluded Regions method is in terms of generic "birds," regardless of age. Both of the quantification methods used inputs rooted (directly and indirectly, respectively) in the DWH Collected Birds Dataset. The "colony sweep" birds are raw records from the DWH Collected Birds Dataset, and have age class information associated with them. In order to allocate $M_{AFS2010}$ into age classes, considering the lack of better information, the Department applied a pro-rating methodology using age class information from the DWH Collected Birds Dataset.

The DWH Collected Birds Dataset contains a data field for age class for each collected bird. Potential values included the following:

- Adult – Of breeding age. Not necessarily in breeding plumage.
- Juvenile – Younger than breeding age.
- After Hatch Year – Older than one year of age. Could include both juveniles and breeding adults.
- Hatch Year – Younger than one year of age.
- N/D – No data available or age could not be discerned.

From the age class information, the proportion of each age class within a species was identified considering only the bird records where age class was identified and excluding records that were not used in the Shoreline Deposition Model[4] (except for the "colony sweep" records, which were included in the analysis of age proportions) and excluding all records dated before August 8, 2010 (Table 1). The numbers of breeding-aged birds are shown in Table 2.

[4] The DWH Collected Birds Dataset contains a data field that facilitates the identification of bird records that were and were not used in the Shoreline Deposition Model. An example of a category of birds excluded from the Model are birds that were collected outside of the geographic area within which bird mortality was being estimated by the Model. See the "data dictionary" for the DWH Collected Birds Dataset for additional information (IEc 2015b).

Table 1: Proportions of breeding aged birds in the DWH Collected Birds Dataset (CBD) for period August 8, 2010 to September 30, 2010, considering only the bird records where age class was identified and excluding all records not used in the Shoreline Deposition Model (SDM) (except including the "colony sweep" records) and excluding records dated before August 8, 2010.

Species	# birds with known age class in CBD	# birds known to be of breeding age in CBD	% breeding-aged birds ($PB_{MBS,AFS2010}$)
American white pelican	2	2	100%
Black skimmer	137	6	4.4%
Brown pelican	156	25	16.0%
Cattle egret	4	1	25.0%
Clapper rail	20	10	50.0%
Common loon	5	3	60.0%
Double-crested cormorant	10	6	60.0%
Forster's tern	8	3	37.5%
Great blue heron	5	4	80.0%
Laughing gull	904	213	23.6%
Least tern	5	3	60.0%
Northern gannet	73	8	11.0%
Roseate spoonbill	1	0	0%
Royal tern	88	40	45.5%
Sandwich tern	22	6	27.3%
Tricolored heron	3	0	0%

Table 2: Number of breeding adults (low and high end of range) that died during the time period August 8, 2010 to September 30, 2010. (Some values may not sum exactly as shown due to numerical rounding issues.)

Species	Shoreline Deposition Model output Aug 8 – Sept 30 ($SDM_{afterAug7}$)		Colony sweep birds	Excluded Regions output Aug 8 – Sept 30 ($ER_{afterAug7}$)		Total Estimated Mortality, all ages Aug 8 – Sept 30 ($M_{AFS2010}$)		# dead breeding-aged birds Aug 8 – Sept 30 (DBB_{2011})	
	low	high		low	high	low	high	low	High
American white pelican	83	133	0	7	13	89	146	89	146
Black skimmer	353	565	125	28	56	506	746	22	33
Brown pelican	2,472	3,958	156	196	389	2,824	4,503	452	721
Cattle egret	92	147	1	7	14	100	163	25	41
Clapper rail	121	193	2	10	19	132	214	66	107
Common loon	155	248	0	12	24	167	272	100	163
Double-crested cormorant	95	153	0	8	15	103	168	62	101
Forster's tern	94	150	5	7	15	106	170	40	64
Great blue heron	115	185	1	9	18	125	204	100	163
Laughing gull	6,831	10,939	273	542	1,076	7,646	12,288	1,804	2,900
Least tern	223	358	7	18	35	248	400	149	240
Northern gannet	879	1,408	1	70	139	950	1,547	104	170
Roseate spoonbill	76	121	3	6	12	85	136	0	0
Royal tern	717	1,148	25	57	113	799	1,286	363	585
Sandwich tern	178	286	9	14	28	201	323	55	88
Tricolored heron	86	138	11	7	14	104	163	0	0
totals	12,570	20,130	619	997	1,981	14,186	22,729	3,433	5,521

4.2.1.2 Proportion of breeding-aged birds to be applied to $LOBM_{output}$

The Live Oiled Bird Model mortality estimate represents the quantifiable portion of the birds that died after September 30, 2010. The LOBM output quantifies the mortality for 63 species, 18 of which represent up to 99% of the LOBM mortality estimate. Only these 18 species are used in the calculation of lost 2011 fledglings generated from the LOBM output in order to simplify the calculation. The LOBM output does not allocate the mortality estimate into age classes. Thus, the proportion of the LOBM output that represented the breeding-aged birds was isolated using the age distributions in the LOBM's input data. Age class information collected during the oiling rate observations of colonial waterbirds (Bird Study #4; Evers et al. 2010), limited to the time period of September 11, 2010[5] to March 31, 2011, was used to identify the proportion of breeding-aged birds for all species except common loon and northern gannet. For these two species the age class proportions were identified using the data from the wintering open-water waterbirds study (Bird Study #12; Evers et al. 2011). However, both studies generated data for American white pelican, and therefore the age information from those two studies were combined. During the oiling rate observations, each bird record was classified as one of the following:

- Adult – Of breeding age. Not necessarily in breeding plumage.
- Immature – Juvenile, younger than breeding age, in sub-adult plumage.
- After Hatch Year – Older than one year of age. Could include both juveniles and breeding adults.
- Nestling – Young that have not fledged yet.
- N/D, Unknown – No data available or age could not be discerned.

Although the LOBM calculations also used bird abundance and oiling rate data generated by other natural resource injury studies, these studies did not generate information on bird age that could be used to allocate the LOBM output into age categories.

The proportion of breeding-aged birds was calculated as the number of bird records identified as adults divided by the total number of bird records with known ages. The proportions of breeding adults used to allocate the LOBM output into age classes are shown in Table 3.

The LOBM estimates mortality after October 1, 2010 by using fate probabilities that estimate the likelihood that an oiled bird would die within the next year. The exact dates of these individual mortalities are not estimated. Thus, data are not available to parse out of the LOBM results those birds that died before or during the 2011 breeding season versus those birds that died after the end of the 2011 breeding season. For the sake of the lost 2011 fledglings calculation, the Department considered the end of the 2011 breeding season to be approximately August 7, 2011, consistent with the Department's lost 2010 fledgling calculation. If a breeding-aged bird died after this date, theoretically, the bird could have successfully fledged chicks before its death. For purposes of the lost 2011 fledgling calculation, and for

[5] Although the LOBM estimates mortality occurring after September 30, 2010, the oiling observation data used spans September 11, 2010 to March 31, 2011, in recognition that most of the birds in the LOBM estimation likely took several days to die. For more information, see the LOBM estimation report (USFWS 2015d).

lack of better information, the Department assumed that all of the breeding-aged birds estimated to have died by the LOBM died before August 7, 2011.

Table 3: Proportions of breeding-aged birds in the oiling rate observations and resulting number of breeding adults (low and high end of range) isolated from the Live Oiled Bird Model output. (Some values may not sum exactly as shown due to numerical rounding issues.)

Species	% breeding adults (PB_{LOBM})	LOBM output ($LOBM_{output}$)		# dead breeding-aged birds after Sept 30 (DBB_{2011})	
		Low	High	Low	High
American white pelican†	0.784	1,836	4,052	1,440	3,178
Black skimmer	0.807	336	734	271	592
Brown pelican	0.446	2,590	6,503	1,156	2,902
Caspian tern	0.889	62	187	55	166
Common loon*	0.811	45	64	36	52
Common tern	0.932	58	127	54	118
Double-crested cormorant	0.211	62	185	13	39
Dunlin	0.959	52	138	50	132
Forster's tern	0.941	16	42	15	39
Great egret	1.000	46	137	46	137
Herring gull	0.493	36	107	18	53
Laughing gull	0.736	146	503	108	370
Northern gannet*	0.731	26	77	19	56
Ring-billed gull	0.704	18	51	13	36
Royal tern	0.786	250	708	197	557
Sanderling	0.720	14	36	10	26
Sandwich tern	0.906	20	44	18	40
White ibis	0.821	508	1,421	417	1,166
Total		6,121	15,116	3,935	9,661

*All information on "% breeding adults" was derived from Bird Study #4, except for those species marked with an asterisk, which were derived from Bird Study #12.

† Age proportion was derived from data combined from Bird Study #4 and Bird Study #12.

4.2.2 Adjustment for natural annual mortality rates

The 2011 breeding season in the northern Gulf of Mexico begins in approximately March. The mortality estimates used as the basis for calculating lost 2011 fledglings represent mortality occurring between August 7, 2010 and August 7, 2011. Some of these birds might have succumbed to natural mortality during that period and would not have been available to breed in 2011 for natural reasons, unrelated to the spill. Therefore, an adjustment to account for natural annual mortality was made using species-specific annual adult survival information obtained from published scientific literature. The annual survival rates (S) (Table 4) were applied to the number of dead breeding-aged birds (DBB_{2011}) to isolate the number of breeding-aged birds not available to breed in 2011 (Table 7).

Table 4: Annual adult survival rates.

Species	Annual Adult Survival	References / Notes
American white pelican	0.787	IEc 2014
Black skimmer	0.72	Gochfield and Burger 1994
Brown pelican	0.82	IEc 2014
Caspian tern	0.89	Gill and Mewaldt 1983
Cattle egret	0.75	Telfair 2006
Clapper rail	0.517	IEc 2014
Common loon	0.895	IEc 2014
Common tern	0.90	Nisbet 2002
Double-crested cormorant	0.85	IEc 2014
Dunlin	0.73	Warnock and Gill 1996
Forster's tern	0.87	Average of values from royal, common, sandwich, and caspian terns
Great blue heron	0.781	IEc 2014
Great egret	0.74	Kahl 1963
Herring gull	0.82	Pierotti and Good 1994
Laughing gull	0.82	IEc 2014
Least tern	0.89	Thompson et al. 1997
Northern gannet	0.94	IEc 2014
Ring-billed gull	0.82	Average of values for herring and laughing gulls
Roseate spoonbill	0.87	Averaged values from black-faced spoonbill (Ueng, Wang, and Hou 2007) and Eurasian spoonbill (Lok 2013).
Royal tern	0.95	Collins and Doherty 2006
Sanderling	0.83	IEc 2014
Sandwich tern	0.72	Shealer 1999
Tricolored heron	0.68	Frederick 2013
White ibis	0.7	Frederick et al. 2011

4.2.3 *Translating # dead breeding birds to # affected pairs*

Published average annual productivity data are generally presented in units of "fledglings per nest," "fledglings per pair," or "fledglings per female." The starting "base number" of dead breeding birds (DBB_{2011}) for the 2011 lost fledglings calculation is in units of breeding-aged individuals, without regard to gender. Thus, DBB_{2011} must be translated into a metric consistent with that of the average annual productivity value. The logical metric to use was "per pair" after considering the following:

- If one assumes that birds only attempt to rear one brood per year (Section 4.1.2), "fledglings per nest" and "fledglings per pair" are functionally equivalent.
- If productivity values that focus on breeding females ("fledglings per female") were used, the lost fledgling calculation would in turn focus on lost breeding-aged females. Assuming a 50:50 sex ratio, the number of affected pairs would equal 1/2 of DBB_{2011}. However, fledglings were also likely not produced in 2011 by males that perished due to the oil spill prior to the 2011 breeding season.

It is theoretically possible, although unlikely, that every individual comprising DBB_{2011}, had they been alive for the 2011 breeding season, could have paired with a mate that survived to the 2011 breeding season (DBB_{2011} = # of affected pairs). The true number of affected pairs (AP_{2011}) to be used in the calculation of lost 2011 fledglings was not known; however, it must be somewhere between DBB_{2011} and ½ of DBB_{2011}. For lack of better information, the midpoint between these two values was used as a point-estimate of the number of affected pairs (AP_{2011} = 3/4 of DBB_{2011}), with DBB_{2011} and ½ of DBB_{2011} used as the maximum and minimum values of a range. The revised conceptual calculation is shown below.

$$DBB_{2011} * S * 0.75 = AP_{2011} \quad \text{(mid-point estimate)}$$

$$AP_{2011} * Productivity = LostFledglings_{2011}$$

4.2.4 *Average annual productivity*

The relevant productivity values are listed in Table 5.

4.3 POTENTIAL BIASES IN APPROACH

This method for estimating lost 2011 fledglings did not account for all of the potential pathways to natural resource injuries that were listed in Section 2. For instance, the spill-related mortality or non-production of eggs and chicks of parent birds that did not die due to the spill. The method also did not quantify any additional lost fledglings due to exposure of eggs or chicks to oil. Many of these pathways listed in Section 2 may have overlapped to contribute to the same lost fledglings. Considering those factors, the preferred methodology would likely produce an underestimate of lost fledglings.

There were also uncertainties associated with the assumptions employed in this methodology. For example, birds that may have been juveniles in 2010 but would have bred for the first time in 2011 are not included in calculating the lost 2011 fledglings. This would likely cause an underestimate of lost fledglings.

The background amount of chick mortality (i.e., amount of mortality that would have naturally occurred in the absence of the spill) was not removed from the calculation results, since such background mortality information was unknown. This would likely cause an overestimate of the 2011 fledglings lost due to the spill.

The lost 2011 fledglings calculation focused on the 24 species that had the highest mortalities calculated by the Shoreline Deposition Model and LOBM. Cumulatively, they comprised up to 91% and 99%, respectively, of those mortality estimates. The lost 2011 productivity from the remaining species was not calculated, and this represents a source of underestimation.

The primary sources of data for the lost 2011 fledgling calculation were the outputs of the Shoreline Deposition Model, the "Excluded Regions" method (which also was rooted in the output of the Shoreline Deposition Model), and the LOBM. As such, all of the limitations and uncertainties associated with the outputs of those models also apply to the lost 2011 fledgling results. These are described in the technical reports for those models (IEc 2015a; USFWS 2015b, 2015d). To the extent these models likely underestimated adult bird mortality, the lost 2010 fledgling calculation would likely also be underestimated.

Lastly, the methodology used here was limited to calculating the fledglings lost during the *first* year that a breeding-aged bird that died after the 2010 breeding season was not able to successfully reproduce. In other words, for birds that died after the 2010 breeding season and before or during the 2011 breeding season, only the lost productivity from the 2011 breeding season was quantified. Theoretically, the breeding-aged birds that died before the 2011 breeding season, had they not been killed, could have reproduced in later years. Calculating that additional lost productivity required additional assumptions on life history parameters and population dynamics modeling, which could not be completed for administrative reasons—the announcement of the natural resource damages Agreement in Principle between BP and the Trustees created a sudden significant shortening of the time the Department had available to complete injury quantification tasks. This contributes to an underestimate of the total fledglings lost due to birds that died between the 2010 and 2011 breeding seasons.

Overall, considering all of the abovementioned factors combined, the limitations and uncertainties would likely contribute to an overall underestimation of lost 2011 fledglings. Given the available information, the results presented here are the Department's best estimate of 2011 fledglings lost due to the spill, recognizing that the true loss is likely higher by some unquantifiable amount.

Table 5: Average annual productivity values (# fledglings per pair per year, assuming one brood per year).

Species	Average annual productivity	References
American white pelican	0.76	IEc 2014
Black skimmer	0.22	Clark et al. 2013; FitzsimmonsNewstead 2015; Pruner, Friel, and Zimmerman. 2011
Brown pelican	1.44	IEc 2014
Caspian tern	1.2	Antolos, Roby, and Collis 2004; Antolos et al. 2006; Cuthbert and Wires 1999; Struger and Weseloh 1985
Cattle egret	1.77	Ranglack, Angus, and Marion 1991; Rodgers 1987; Telfair 2006
Clapper rail	5.5	IEc 2014
Common loon	0.51	IEc 2014
Common tern	1.2	Chapdelaine et al. 1985; Erwin and Smith 1985; Hall and Kress 2004; Nisbet 2002; Nisbet and Drury 1972; Nisbet and Welton 1984; Safina et al. 1988; Safina, Witting, and Smith 1989
Double-crested cormorant	1.79	IEc 2014
Dunlin	1.6	Holmes 1966
Forster's tern	0.6	King, Custer, and Quinn 1991
Great blue heron	0.35	IEc 2014
Great egret	0.5	Frederick and Collopy 1989; McCrimmon, Ogden, and Bancroft 2011
Herring gull	1.4	Boyne 1999; Burger 1984; Kadlec and Drury 1968; Pierotti and Annett 1991; Pierotti and Good 1994
Laughing gull	0.97	IEc 2014
Least tern	0.6	Thompson and Slack 1984; Thompson et al. 1997
Northern gannet	0.75	IEc 2014
Ring-billed gull	1.4	Pollet et al. 2012; Brown and Morris 1995
Roseate spoonbill	1.44	Lorenz et al. 2009; White, Mitchell, and Cromartie 1982
Royal tern	0.42	Owen and Pierce 2014
Sanderling	1.51	IEc 2014
Sandwich tern	0.41	Owen and Pierce 2014
Tricolored heron	0.9	Frederick 2013; Frederick and Collopy 1989; Frederick, Spalding, and Powell 1993
White ibis	0.5	Frederick and Collopy 1989; Frederick and Jayasena 2011; Semones 2003

5 RESULTS FROM PREFERRED METHODOLOGY

Using the information described above, the numbers of lost 2011 fledglings are shown in Table 8. Due to the mortality of breeding-aged birds during the period of August 8, 2010 to August 7, 2011, 2,816 to 11,568 fledglings were lost in 2011.

Table 6: Total dead breeding-aged birds (DDB_{2011}) from period August 8, 2010 to August 7, 2011.

Species	Total DDB_{2011} (Aug 8, 2010 - Sept 30, 2010 and Oct 1, 2010 - Aug 7, 2011)	
	low end of range	high end of range
American white pelican	1,529	3,324
Black skimmer	293	625
Brown pelican	1,608	3,623
Caspian tern	55	166
Cattle egret	25	41
Clapper rail	66	107
Common loon	137	215
Common tern	54	118
Double-crested cormorant	75	140
Dunlin	50	132
Forster's tern	55	103
Great blue heron	100	163
Great egret	46	137
Herring gull	18	53
Laughing gull	1,912	3,270
Least tern	149	240
Northern gannet	123	226
Ring-billed gull	13	36
Roseate spoonbill	0	0
Royal tern	560	1,142
Sanderling	10	26
Sandwich tern	73	128
Tricolored heron	0	0
White ibis	417	1,166
Total	7,368	15,182

Table 7: Total dead breeding-aged birds (after adjusting for annual adult survival) that were not available to breed in 2011, and resulted number of affected breeding pairs.

Species	Total dead breeding-aged birds that were not available to breed in 2011		# affected pairs (AP_{2011})	
	low	high	low	high
American white pelican	1,204	2,616	602	2,616
Black skimmer	211	450	106	450
Brown pelican	1,318	2,971	659	2,971
Caspian tern	49	148	25	148
Cattle egret	19	30	9	30
Clapper rail	34	55	17	55
Common loon	122	193	61	193
Common tern	49	107	24	107
Double-crested cormorant	64	119	32	119
Dunlin	36	97	18	97
Forster's tern	48	90	24	90
Great blue heron	78	127	39	127
Great egret	34	101	17	101
Herring gull	15	43	7	43
Laughing gull	1,568	2,682	784	2,682
Least tern	132	214	66	214
Northern gannet	116	213	58	213
Ring-billed gull	10	29	5	29
Roseate spoonbill	0	0	0	0
Royal tern	532	1,085	266	1,085
Sanderling	8	22	4	22
Sandwich tern	53	92	26	92
Tricolored heron	0	0	0	0
White ibis	292	816	146	816
Total	5,993	12,299	2,996	12,299

Table 8: Total lost 2011 fledglings (low and high end of range), all calculations combined.

Species	Total Lost 2011 fledglings	
	low end of range	high end of range
American White Pelican	457	1,988
Black Skimmer	23	99
Brown Pelican	949	4,278
Caspian Tern	29	178
Cattle Egret	17	54
Clapper Rail	94	305
Common Loon	31	98
Common Tern	29	128
Double-crested Cormorant	57	213
Dunlin	29	155
Forster's Tern	14	54
Great Blue Heron	14	45
Great Egret	9	51
Herring Gull	10	61
Laughing Gull	760	2,601
Least Tern	40	128
Northern Gannet	44	160
Ring-billed Gull	7	41
Roseate Spoonbill	0	0
Royal Tern	112	456
Sanderling	6	32
Sandwich Tern	11	38
Tricolored Heron	0	0
White Ibis	73	408
Total	2,816	11,568

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Appendix A: Common and scientific names of the bird species mentioned in the Quantification of Lost 2011 Fledglings.

Common name	Scientific name
American white pelican	*Pelecanus erythrorhynchos*
Black-faced spoonbill	*Platalea minor*
Black skimmer	*Rynchops niger*
Brown pelican	*Pelecanus occidentalis*
Caspian tern	*Hydroprogne caspia*
Cattle egret	*Bubulcus ibis*
Clapper rail	*Rallus longirostris*
Common loon	*Gavia immer*
Common tern	*Sterna hirundo*
Double-crested cormorant	*Phalacrocorax auritus*
Dunlin	*Calidris alpina*
Eurasian spoonbill	*Platalea leucorodia*
Forster's tern	*Sterna forsteri*
Great blue heron	*Ardea herodias*
Great egret	*Ardea alba*
Herring gull	*Larus argentatus*
Laughing gull	*Leucophaeus atricilla*
Least tern	*Sternula antillarum*
Northern gannet	*Morus bassanus*
Ring-billed gull	*Larus delawarensis*
Roseate spoonbill	*Platalea ajaja*
Royal tern	*Thalasseus maximus*
Sanderling	*Calidris alba*
Sandwich tern	*Thalasseus sandvicensis*
Tricolored heron	*Egretta tricolor*
White Ibis	*Eudocimus albus*